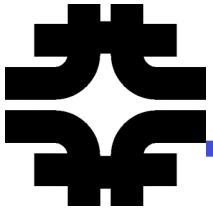


Status of NuMI/MINOS Operations

Gina Rameika

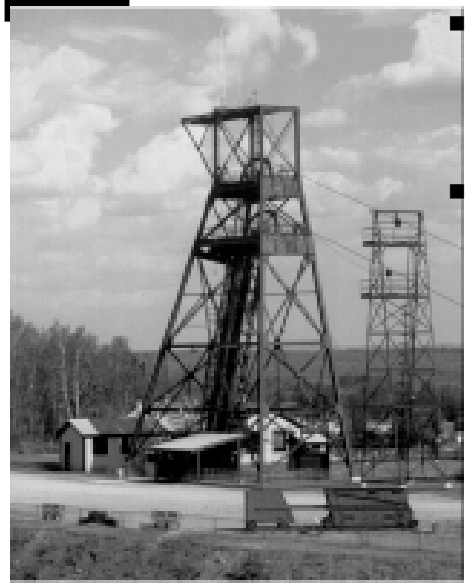
DOE Tevatron Operations Review

March 27, 2007

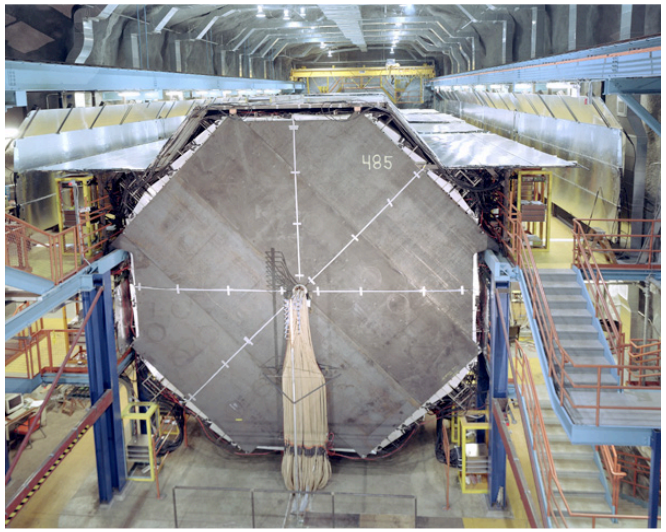
Outline

- Introduction
- Proton Intensity (2005 - 2007)
- Operations Performance
- Safety
- Effort
- Computing
- Physics Analysis
- Outlook & Conclusions

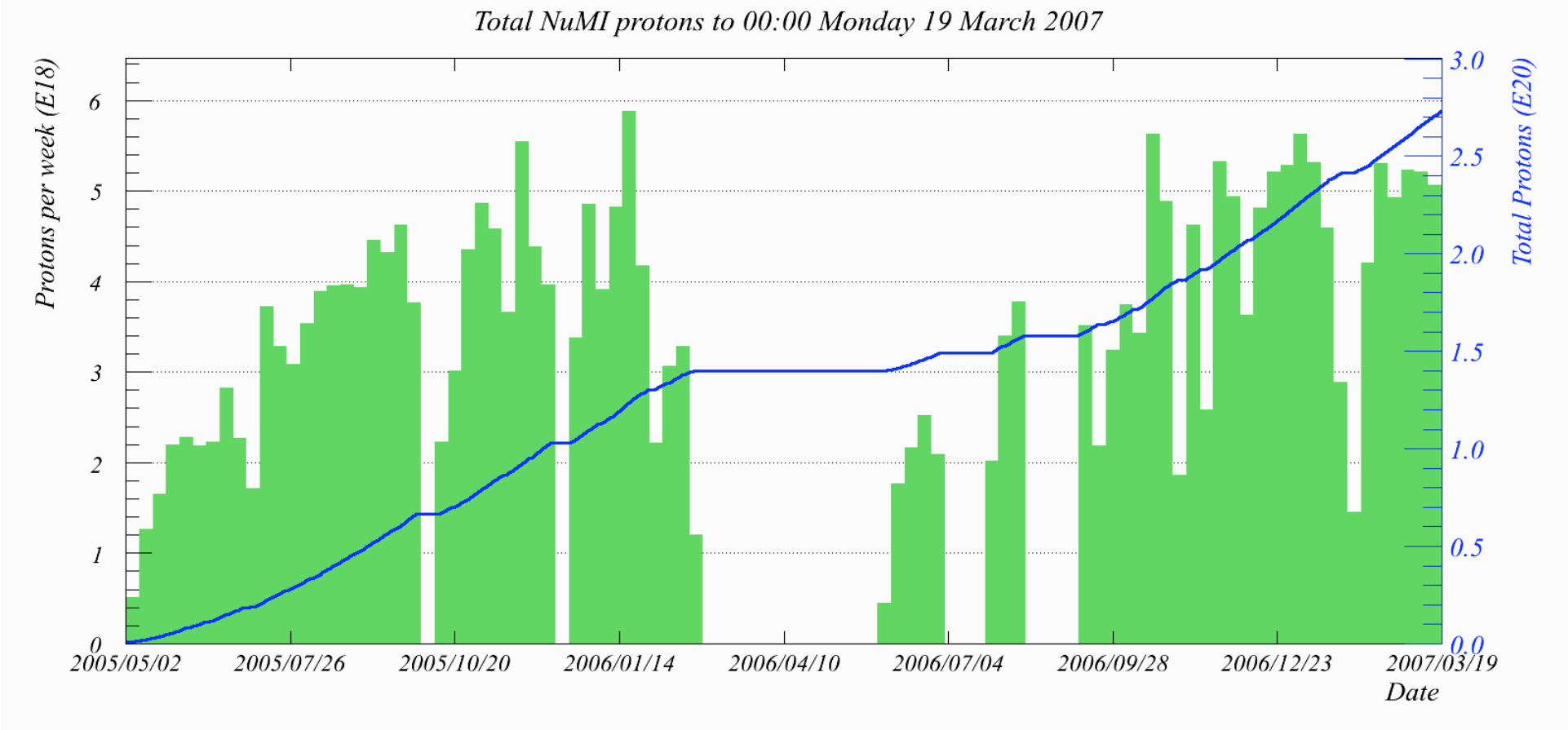
Introduction



- MINOS uses the NuMI Beam produced by the 120 GeV MI
- MINOS operates two detectors
  - MINOS Near Detector Hall (1.2 km)
  - Soudan Underground Laboratory (735 km)
  - MINOS Control Room - WH12NW



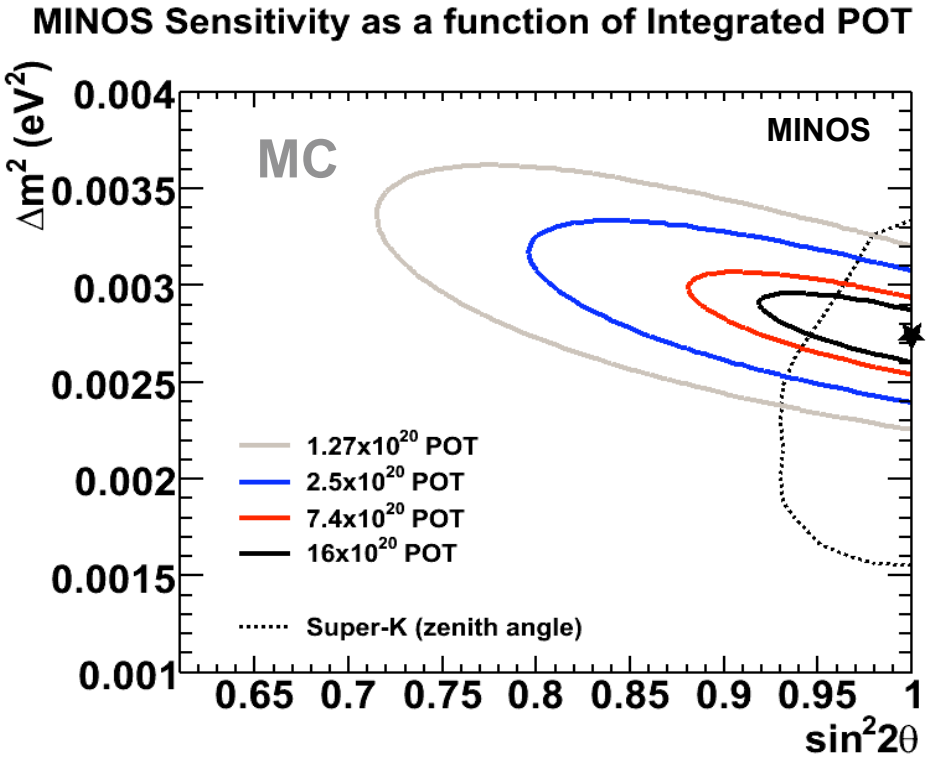
Proton Intensity



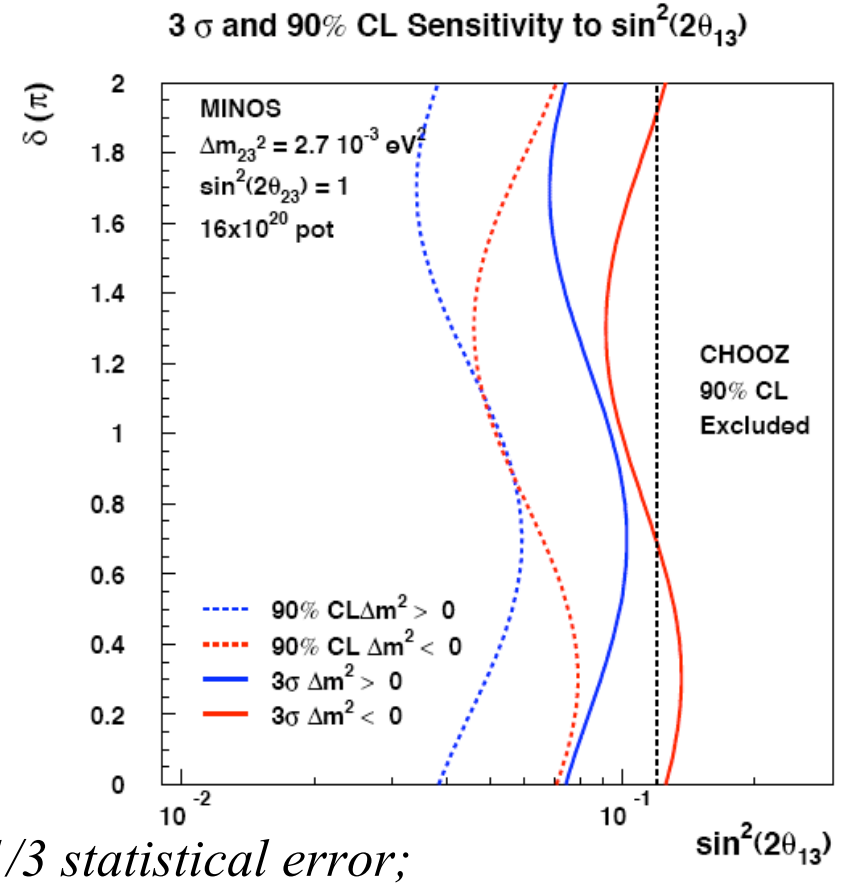
- Physics data set since May 2005 : 2.744E20
- Since June 2006 : 1.35E20
- This physical year : 1.066E20

Why Protons Matter?

ν_μ disappearance

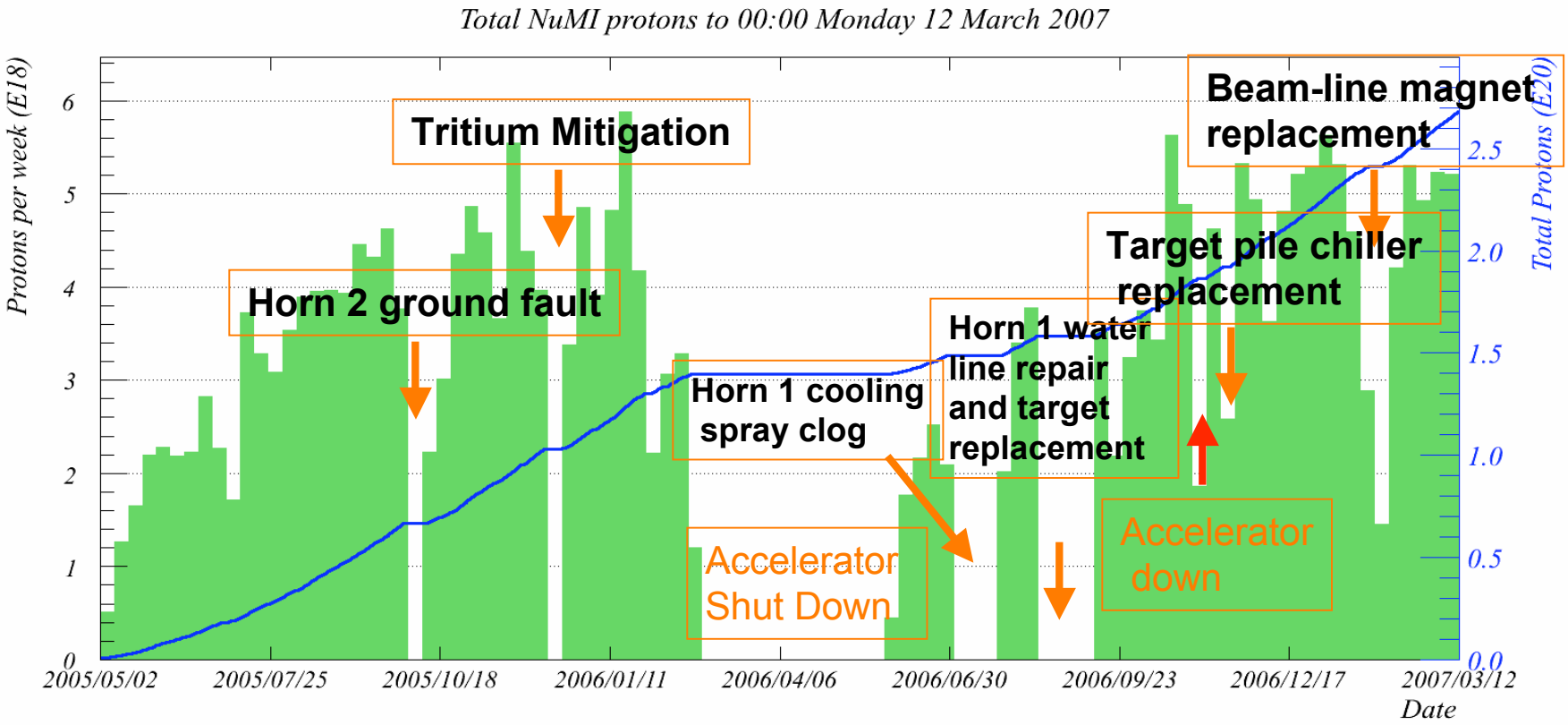


$\nu_\mu \rightarrow \nu_e$



Presently our systematic error is ~1/3 statistical error;
MINOS goal is to get 11x10^{20} by end of 2009

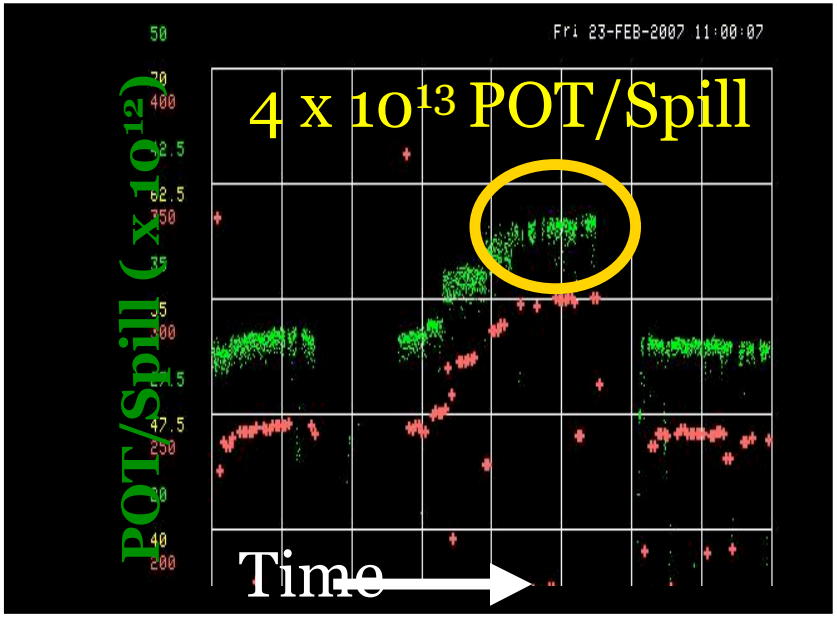
NuMI Performance



Operations Performance Issues

Target

- Beam Power -> Mechanical stress
  - At 4e13 ppp we have a safety factor of 1.4 with a 1 mm spot size
- Reduce stress and increase the safety factor by increasing the beam spot size
  - When we run greater than 4e13 ppp we will increase the spot size to 1.3 mm



Operations Performance Issues

Spares Inventory

- Most important elements : target and horns

HORNS	PH1-00	PH1-01	PH1-02	PH1-03	PH1-04	PH1-05		PH2-01	PH2-02	PH2-03	PH2-04
in use	**proto**	**in use**						**in use**			
fiducialize (survey)											
instrumentation											
water tank, hangers											
test pulse			2/3								
stripline											
water lines etc											
I.C.+O.C assem											
O.C. silvered											
O.C. coated											
O.C. welds											
O.C. machined											
O.C. blanks											
I.C. silvered											
I.C. coated											
I.C. welds			7/7	3/7	3/7	3/7			6/6	5/6	
I.C. machined											5/7
I.C. blanks											
					700kW	700kW					700kW

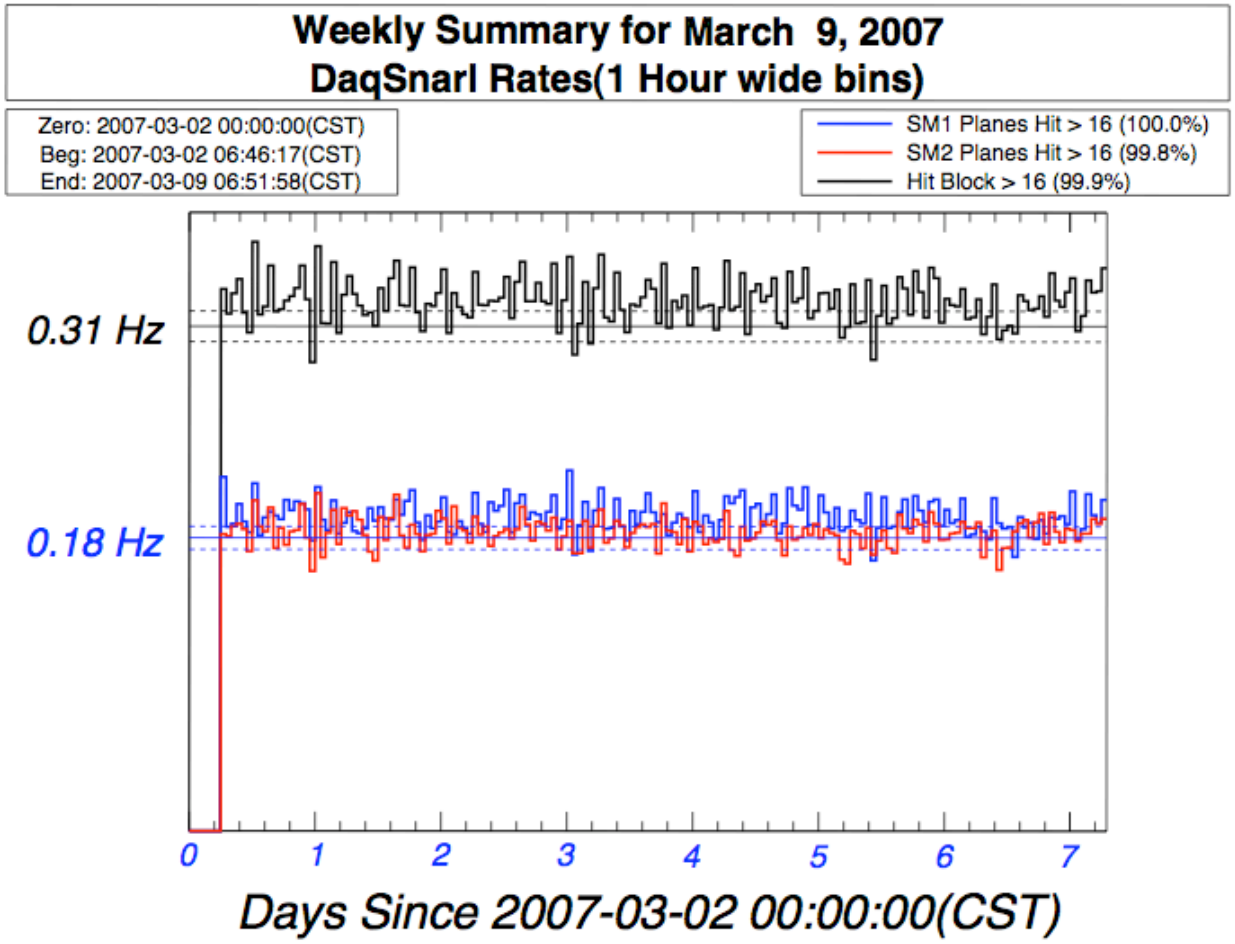
TARGETS	NT-01	NT-02	NT-03	NT-04
in use	**stuck**	**in use**		
fiducialize (survey)				
instrumentation				
hangers				
mount target + baffle				
fab carrier				
fiducialize target				
fab target + baffle				ordered

Color code

	Used
	Done
	In progress
	to do

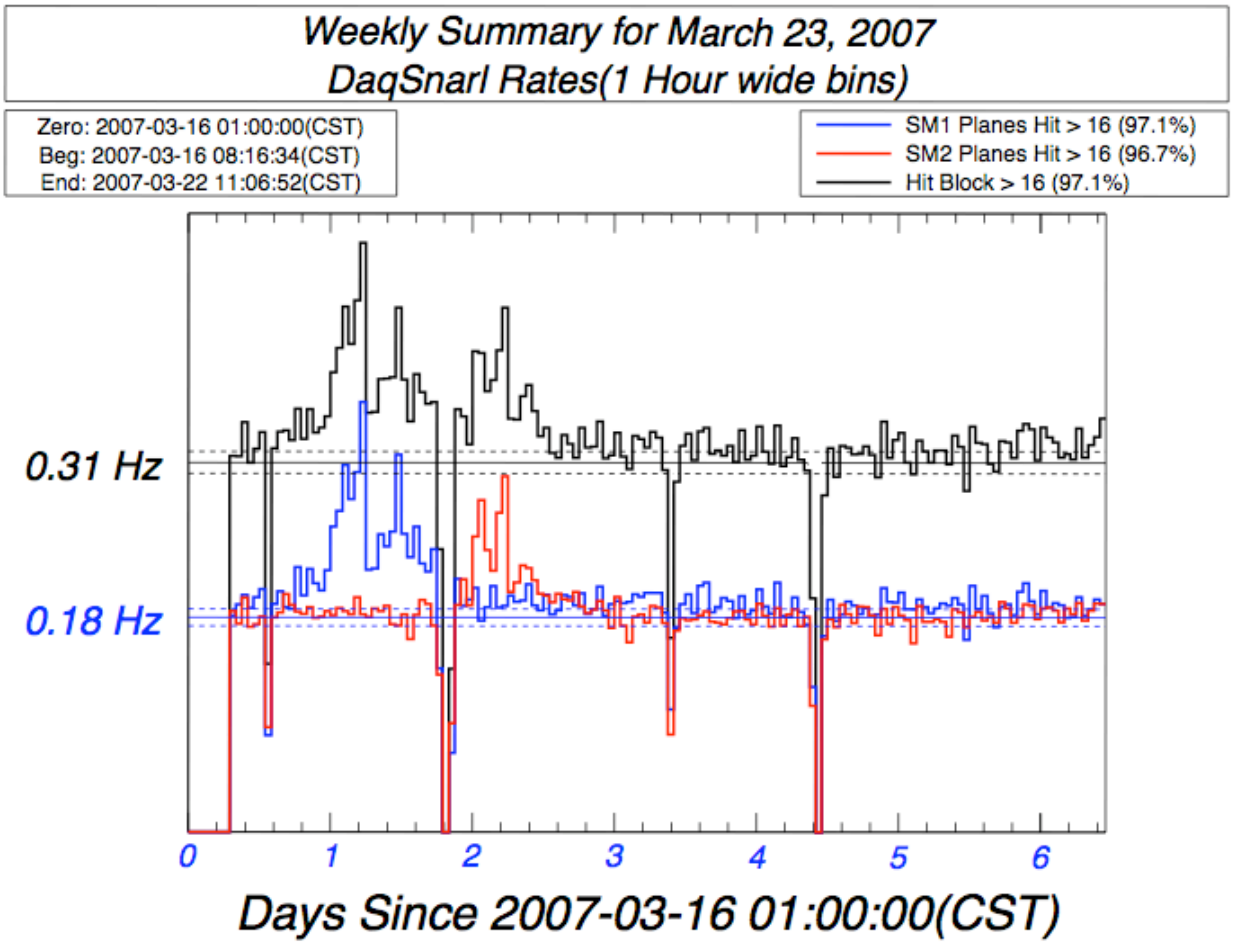
Operations Performance - Far Detector

Daily detector performance is monitored with cosmics



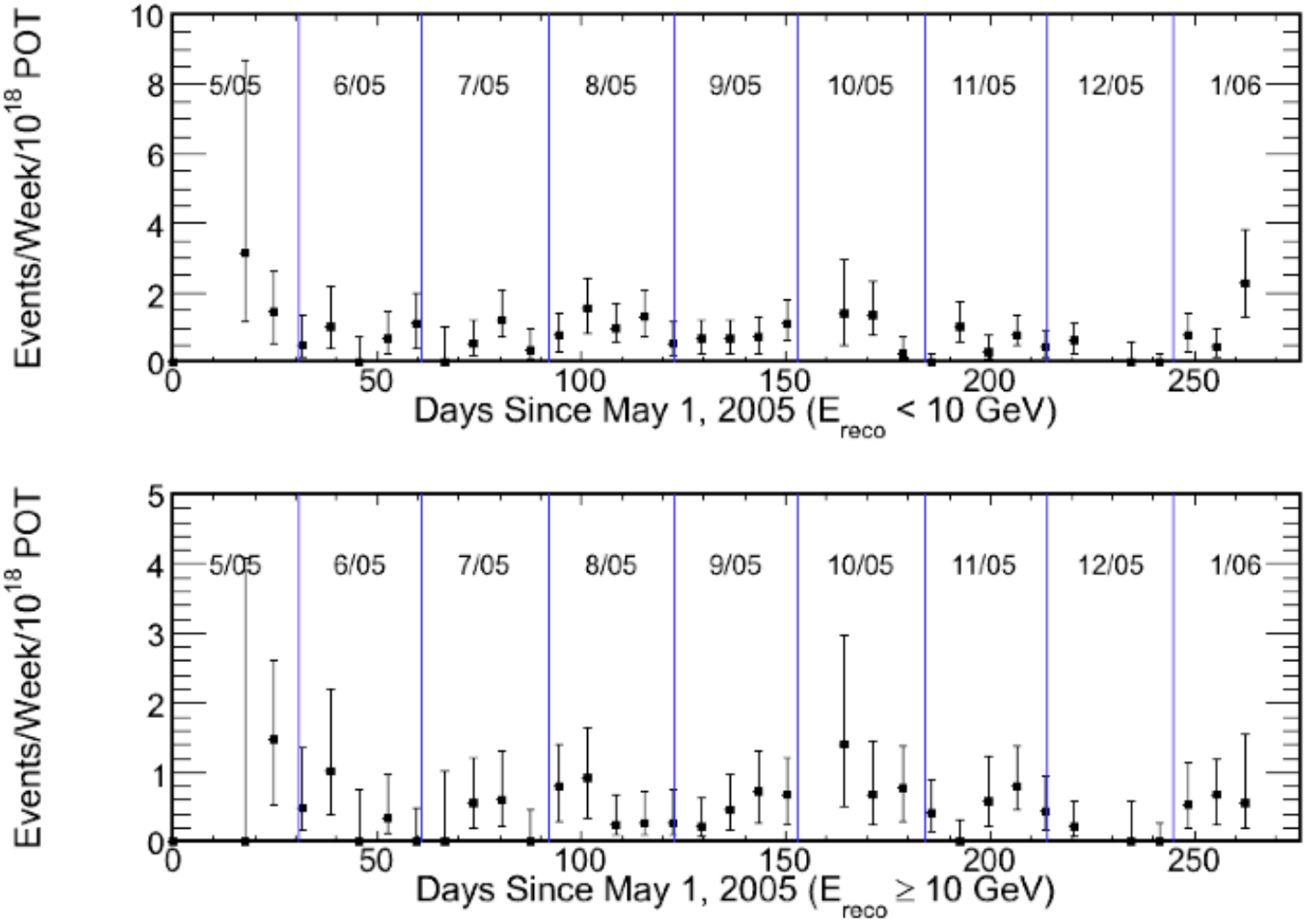
Operations Performance - Far Detector

Daily detector performance is monitored with cosmics

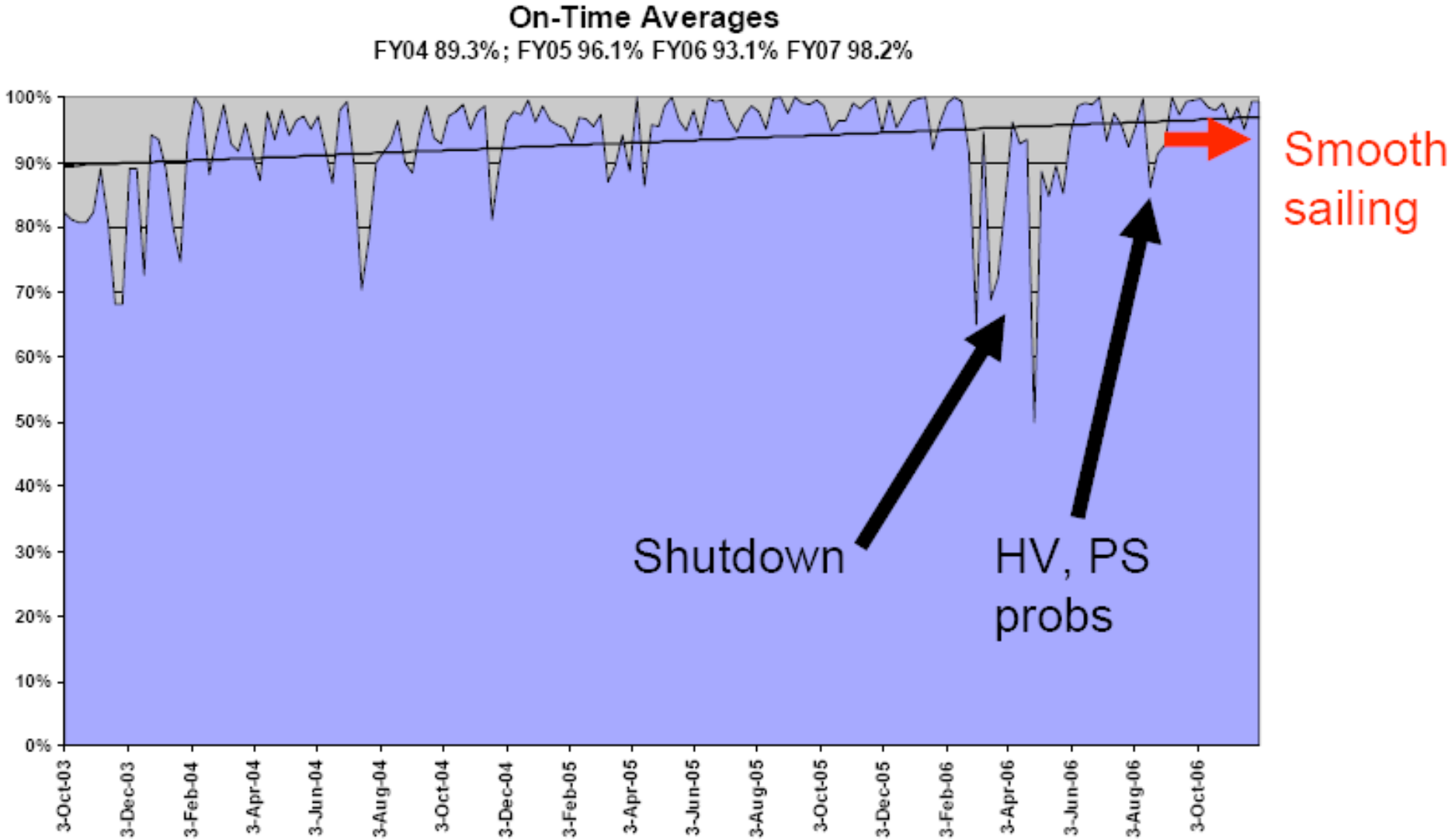


Operations Performance - Far Detector

Expect only a few beam induced neutrino events per day

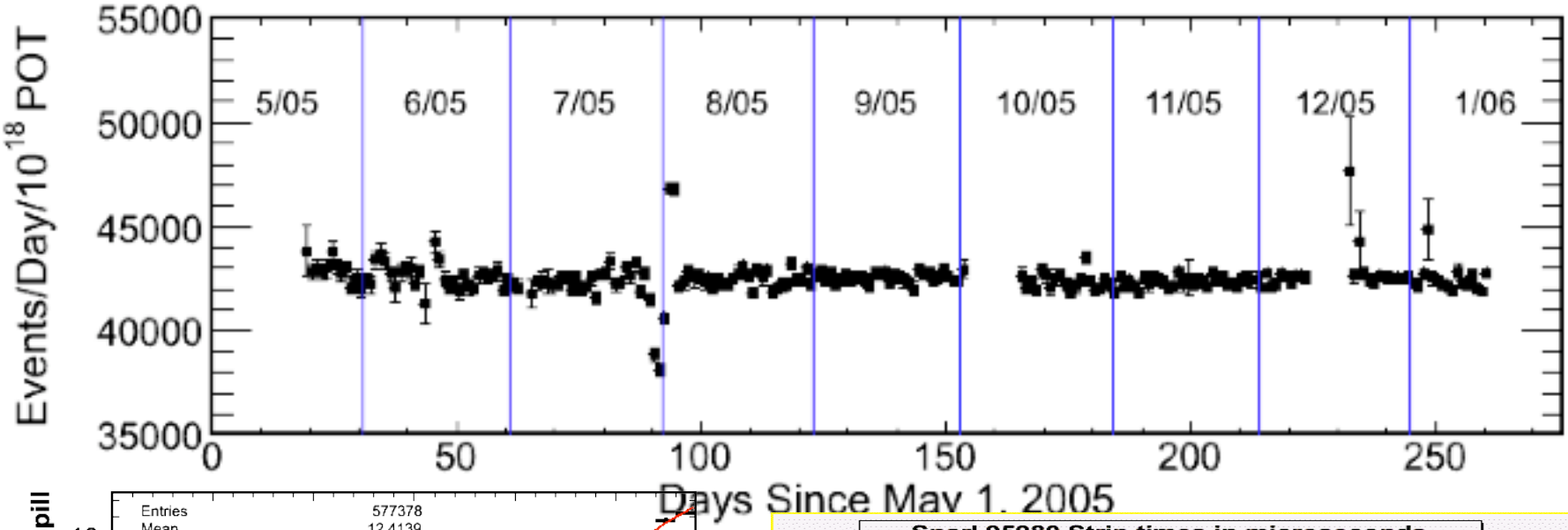


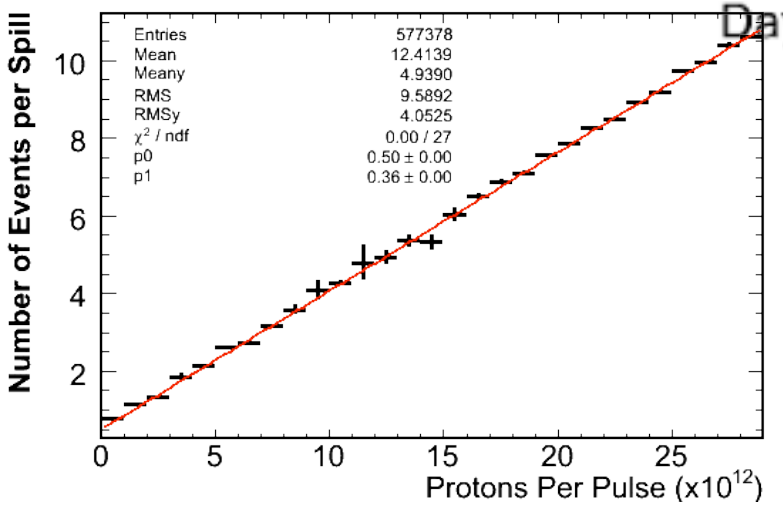
Operations Performance - FD

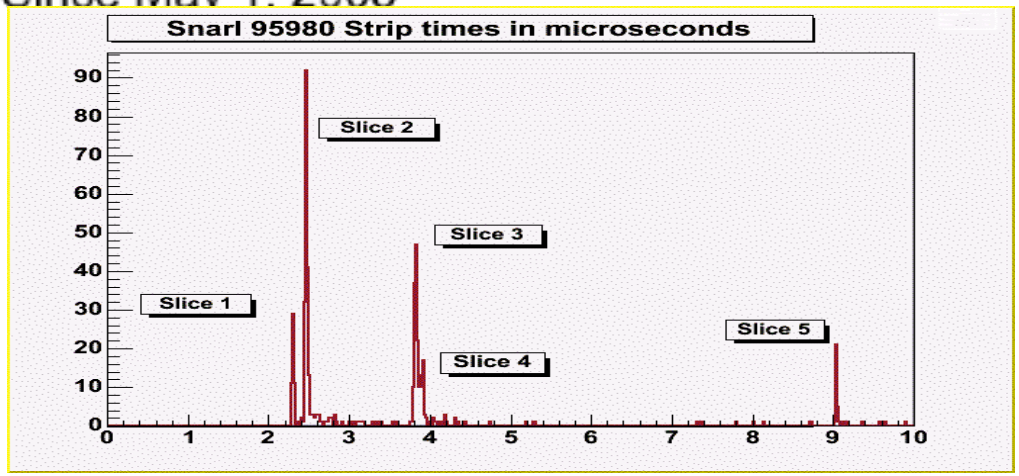


Operations Performance - Near Detector

High event rate

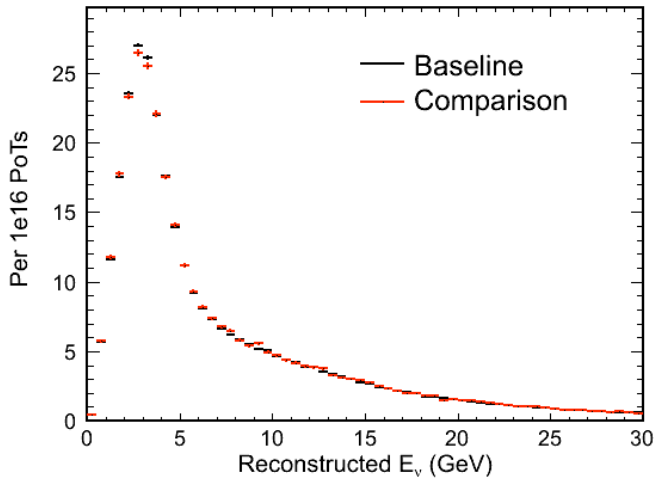


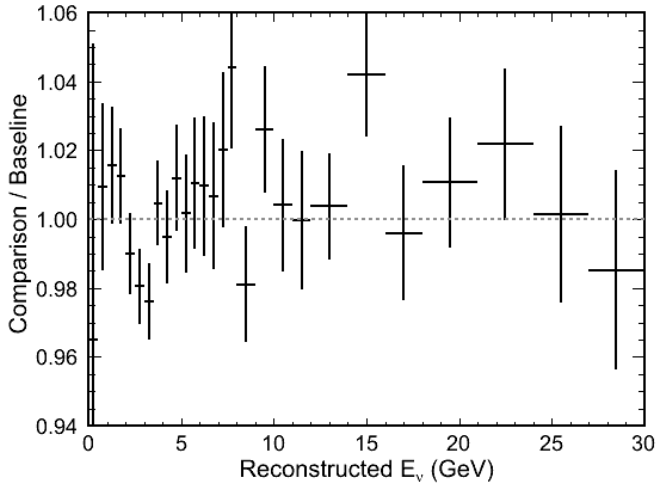


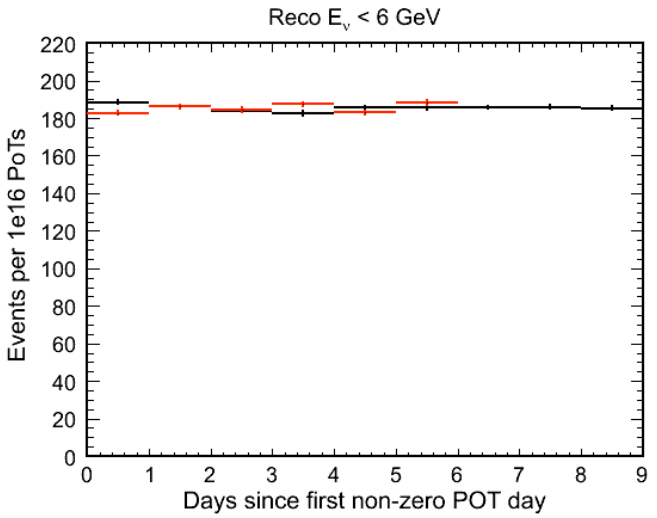


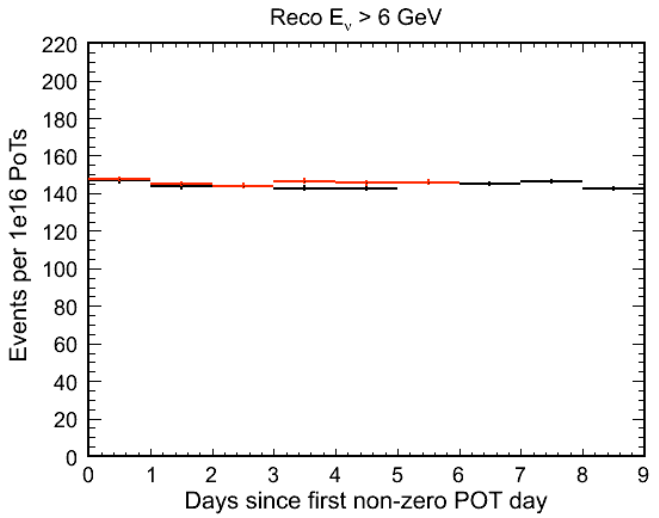
Operations Performance - Near Detector

Weekly performance is monitored against a standard baseline









Operations Performance Issues - ND

Front End Electronics

- MENU (QIE - ADC) failures : 0.5 - 1 per day
  - Weekly repair cycle
  - Typically 4 - 7 dead channels (out of ~10K)
  - Negligible impact on data quality
  - 95% of failed cards have been repaired
- Other component failures - rare (~2 per year)
- Spares
  - MENU : 2.2%
  - OTHER : 5 - 10%
  - Engineers recommends producing 500 new MENU and 5 new Keeper modules

LCW Cooling

- Temperature is steadily rising
  - OK for now, but continued increase will reduce the lifetime of the front ends
- Correlated with rising groundwater temp
- May need to add a chiller (working on a cost estimate)

Safety at NuMI/MINOS

- No reportable incidents in past year
- Underground Areas
  - Access controlled by badging and keys
  - Training verification
  - Regular Inspections to verify material control requirements
  - Pumps inspected/tested on a monthly basis
  - FESS conducts annual "top to bottom" infrastructure inspection
- Training
  - Underground access
    - Underground Training for all areas : Requires annual refresher class (on-line)
      - Includes access control procedures
      - Emergency evacuation
      - PPE
      - Magnetic Field
  - NuMI Radiation Areas : add in Rad Worker, LOTOII and Controlled Access (CA)
  - MINOS Hall : GERT
  - MUON Alcoves (CA)
- NuMI
  - Target Hall, Target/Horn repairs require strict observance of ALARA (component activation)
  - Target Hall tritium monitoring/mitigation plan in place
- MINOS Hall
  - New Projects (i.e. MINERVA exp)
    - Hazard Analysis, Work Planning
    - Newly formed Cryo Review Committee

Safety at Soudan

Safety at the Soudan Underground Lab is the responsibility of the University of Minnesota

- Lab Safety Plan
  - Documents approved by U of M Occupational Safety Department, DNR regional safety officer and Fermilab ES&H
- Joint Safety Review Committee (meets monthly)
  - Review on-site issues with U of M and DNR
- Experimental Planning Committee
  - Review new experiments that want to move to Lab
- Monthly inspections
  - Cranes, fork lifts, trucks, fire extinguishers, emergency lights
- Yearly inspections
  - University Occupational Safety and Health
  - University Code Officials
  - University Radiation Safety
  - Fermilab ES & H- Keith Schuh
  - Rutherford National Lab-Health and Safety Division
  - Minnesota DNR Regional Safety Officer
- Yearly inspections by outside experts
  - Fire alarm and sprinkler system
  - Fire extinguishers
  - Elevator

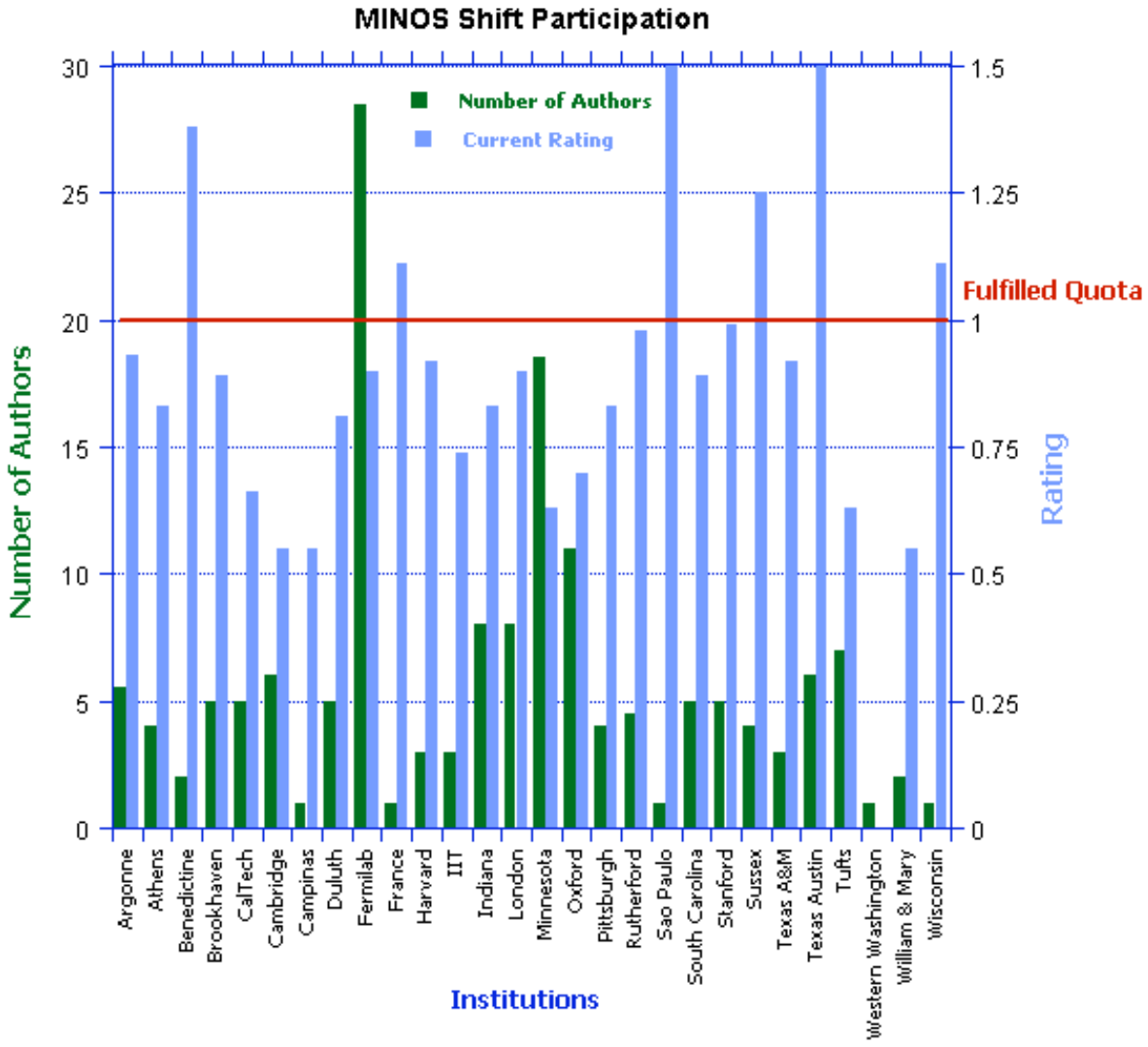
Technical and Scientific Manpower

- Shifts
  - Soudan Underground
    - 8 FTE (Facility, MINOS, CDMS)
    - M-F 7:30am - 5:00 pm
    - 24/7 on-call (16/69 MINOS related in FY06)
  - Fermilab (WH12NW Control Room)
    - 24/7 ; (4) 7-hr shifts ; 1 hr overlap (2 persons) on each end
    - On-site Run Coordinator
- Maintenance and Repairs
  - Far Detector
    - Minecrew (daily)
    - UMD (Operation's Manager & Detector Control experts, weekly)
    - UK DAQ experts (periodic)
  - Near Detector
    - Local (resident) physicists - electronics repair (available daily)
    - Argonne engineer/technicians (as needed)
    - IIT technical support (as needed)

Collaboration Shift Requirements

- Author list updated annually
- Shift need determined by running schedule
- Institutional shift responsibility determined by # of authors
- Sign up voluntary
- Unfilled shifts get filled by assignment to institutions with lowest fulfilled quota

Goal : Blue ⇒ 1



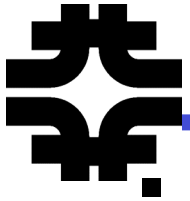
DAQ Maintenance and Support

Responsibility of UK Collaborators

- One full time person available 100% to DAQ issues
  - This level is generally not needed, so this person does work on other projects
- 5 additional UK experts available at a fraction of their time, summing to approximately a second FTE
- UK provides 24/7 on-call support via YELL-DAQ
- These groups conduct periodic, on-site, scheduled maintenance
  - ~35% of an FTE last year
- UK groups have financial responsibility for DAQ hardware

System Performance

- Very low hardware failure rate
  - 1 - 2 processors per year
  - Usually associated with power interruptions
- Use shutdowns to install system upgrades



Offline Computing

General Strategy

- Integrate MINOS systems into central lab facilities as much as possible
  - Dedicated ASF disk space - managed by Central Services in CD
  - Linux cluster (25 nodes) administered by Fermilab Experiments Facilities dept in CD
  - Use LSF batch node but are migrating to FermiGrid
  - Oracle Database (used for SAM handling) - supported by the Database Administrators department
  - Dedicated poole of Dcashe disk managed by Storage Service Administration in CD
    - 8 Tbytes in AFS, 15 Tbytes in Dcashe
    - 1.1 M files and 73 Tbytes in the Enstore Tape Robot
  - Use FermiGrid for reconstruction

Offline Computing

- Far Detector
  - Record and reconstruct *all* cosmics (plane and energy triggers)
  - Record and reconstruct *all* activity within the beam spill window
- Near Detector
  - All cosmics (10/12 plane trigger) recorded
  - reconstruct 1/6 of cosmics
  - Record and reconstruct all events in beam spill
- Data acquisition and analysis of beamline data integrated into the processing of raw data
  - Spill timing
  - Protons on target
  - Status and values of beamline devices

Offline Computing

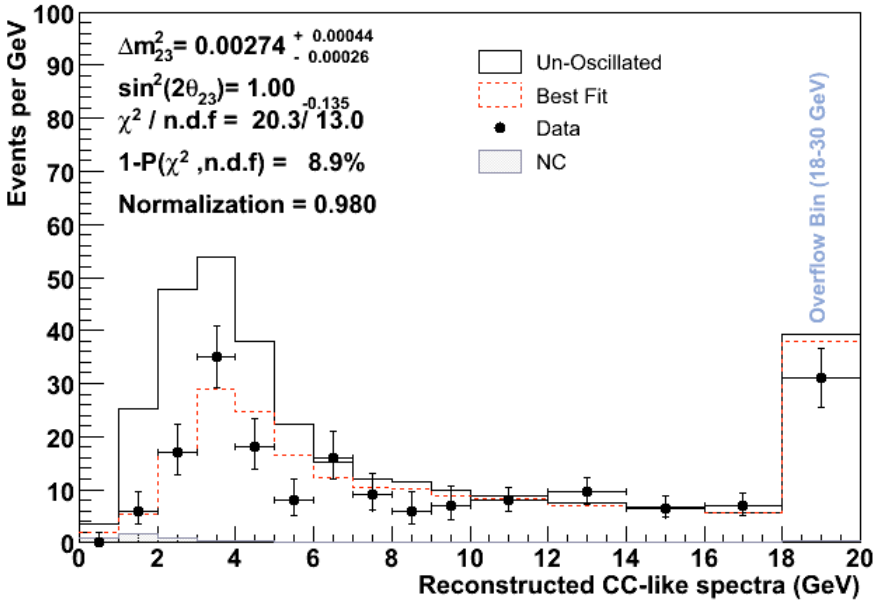
- Major Activities
  - Calibration
    - Full calibration done for 1st physics set (1.27e20)
    - Second round to be done for data through April 1
    - Time/manpower intensive -> 1/year full update
  - Monte Carlo
    - Just finished our 3rd major update/release
    - ~ 3 month job to meet major needs
  - Reconstruction
    - Also just finished our 3rd major update/release
    - 1 - 2 months for all data reprocessing
- Strategy
  - Major releases and reprocessing done on ~ an annual basis

Computing Resources

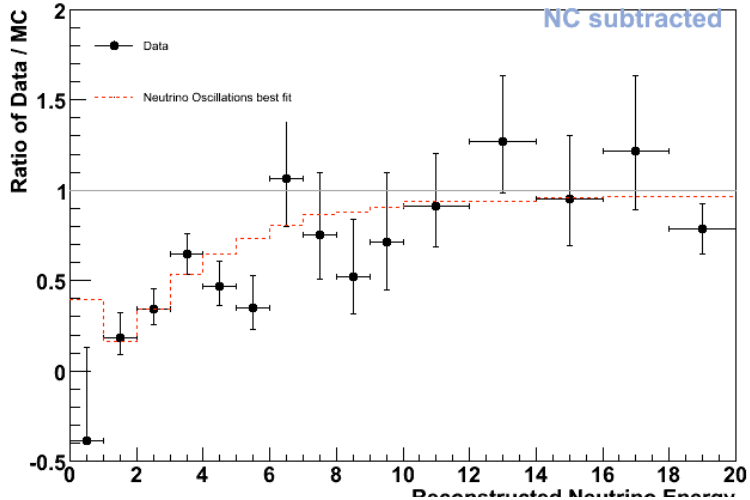
- Effort
  - Computing Division
    - 1.5 persons dedicated to MINOS support of daily computing operations and control room systems
    - 1 person dedicated to MINOS software infrastructure
    - 1 physicist serves as liason between experiment and CD
  - Collaboration (includes FNAL researchers)
    - Core Off-line Software -> reconstruction
    - Raw data processing -> standard reconstruction ntuple (data and MC)
    - Calibration (cosmic rays, test beam correlation, light injection)
    - Physics analysis groups produce reduced Analysis Ntuples
- Off Site CPU power - Monte Carlo Production
  - 350 Ghz
    - Rutherford/Caltech (Near)
    - William & Mary (56Ghz) (Far)
  - Additional 224Ghz coming soon at Tufts
  - Need ~ 3mos to run most of the requested MC data sets

Physics Analysis

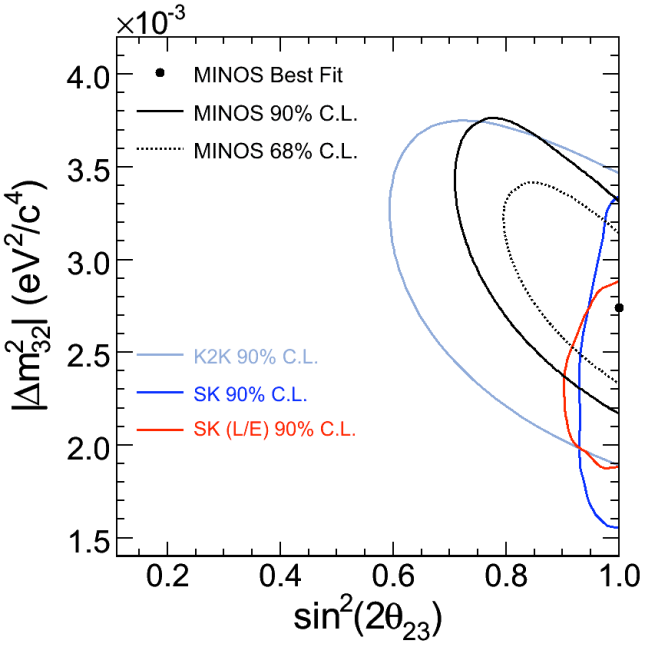
Oscillation Results for 1.27E20 p.o.t



Phys. Rev. Lett. 97 (2006) 19180



- Strong energy-dependent suppression of ν_μ events observed (**5.9 standard deviation effect below 5 GeV**)
- Consistent with the neutrino oscillation hypothesis
- **With more data, we can test and rule out alternative hypotheses, such as neutrino decay, which predict a different energy dependent suppression of the ν_μ rate**



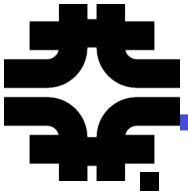
Physics Analysis Groups

- ν_μ CC disappearance : Δm^2_{32} and $\sin^2(2\theta_{23})$
  - An updated analysis will be presented this summer with a factor of two larger exposure
- Neutral Currents : Set limits on $f_{sterile}$
  - Collaboration has blessed the "ND" NC spectrum
  - Plan 1st "box opening" this summer
- Electron neutrinos
  - ν_e search will see a signal if θ_{13} is around the Chooz limit
- Beam ν_μ-bar
  - Measure oscillations -> Limits on CPT invariance
- Atmospheric neutrinos (ν + ν-bar + ν_e)
  - ν-induced muon events + contained vertex events (1st results on 2-3 years of exposure)
  - Now doing a combined analysis
  - Doubled statistics in ~ 3years
- Cosmic rays (13/sec Near; 1/2sec Far)
  - Charge sign, seasonal variations, moon/sun shadow
- Near Detector Physics
  - Millions of events in a broad band beam
  - Cross sections : ν + ν-bar + ν_e

Publications

- **Charge-separated atmospheric neutrino-induced muons in the MINOS far detector.** By MINOS Collaboration. FERMILAB-PUB-07-012-E, BNL-77481-2007-JA, Jan 2007. 14pp. e-Print Archive: **hep-ex/0701045 - accepted to PRD**
- **Observation of muon neutrino disappearance with the MINOS detectors and the NuMI neutrino beam.** By MINOS Collaboration (D.G. Michael *et al.*). FERMILAB-PUB-06-243, BNL-76806-2006-JA, Jul 2006. 6pp. Published in **Phys.Rev.Lett.97:191801,2006**. e-Print Archive: **hep-ex/0607088**
- **First observations of separated atmospheric nu(mu) and anti-nu(mu) events in the MINOS detector.** By MINOS Collaboration (P. Adamson *et al.*). FERMILAB-PUB-05-525, Dec 2005. 18pp. Published in **Phys.Rev.D73:072002,2006**. e-Print Archive: **hep-ex/0512036**

- **In preparation :**
  - **Measurement of the Atmospheric Muon Charge Ratio at TeV energies with MINOS**
  - **Measurement of Neutrino Velocity with the MINOS detectors and NuMI Neutrino Beam**
  - **PRD of 1st oscillation measurement**



Outlook & Conclusions

- MINOS Near and Far Detectors operate at high efficiency with low maintenance and repair demands
- The MINOS collaboration is maintaining smooth operations with a shift program that meets the needs of the experiment
  - Continued support for University Groups is essential for collaborators to be able to maintain this support
- NuMI performance is good, but increased POT/spill and reliable 2.2 sec cycle time is necessary to reach physics goals
- MINOS data is reconstructed and available for physics analysis within days of being taken